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ENHANCEMENT OF X-RAY IMAGE: A REVIEW

T P MITHUN[1], SUDARSHAN B G[2] & ABHILASHAGOUDA KARIGOUDAR[3]

[1]Assistant Professor, Department of Telecommunication, R V College of Engineering, Bangalore, Karnataka, India

[2]R V College of Engineering, Health Center, Bangalore, Karnataka, India

[3]Student, Department of Telecommunication, R V College of Engineering, Bangalore, Karnataka, India

ABSTRACT

X-ray image is the noninvasive medical test used for the verification of bone anatomy and bone structure. X-ray image sometime lack bone details and sharpness. This paper uses the layer difference representation (LDR) contrast enhancement (CE) and contrast limited adaptive histogram equalization (CLAHE) methods as a pre-processing CE technique and uses Gaussian filtering operation for increasing the sharpness and structural view of radiographic images of bones. The total process helps to improve the image quality highlighting fine structures of digital bone X-ray images. MATLAB2012b image processing toolbox was used for simulation and verification.

KEYWORDS: Contrast Enhancement, Layer Difference Representation, Contrast Limited Adaptive Histogram Equalization, Gaussian Filtering

INTRODUCTION

X-Ray images are being used to image internal structure of the human body by radiologists for recognizing the internal problems. Due to lack of sharpness in these images it becomes difficult to view the details like edges and high frequency elements. So, enhancement of high frequency elements will effectively help in overcoming the above problems. Enhancement of high frequency element includes enhancement of image's contrast.

For enhancement of X-ray images, Firstly, selecting the best contrast enhancement technique plays the important role. Captured images often fail to preserve scene details faithfully or yield poor contrast ratios due to limited dynamic ranges. CE techniques [1] can reduce these problems and bring out hidden details. CE techniques can be classified into global and local approaches. A global approach obtains a single transformation function, which applies to all pixels in an entire image. For example, the gamma correction based on the simple power law CE technique. Whereas local approach applies the transformation function for each pixel adaptively according to the information in a local neighborhood pixels. But a local approach demands higher computational complexity and its level of CE is hard to control. So, global CE techniques are widely used in the practical applications.

Histogram equalization (HE) [1] is the most widely used technique to enhance low contrast images due to its simplicity and effectiveness, however it has some drawbacks, such as contrast over-stretching, noise amplification. To overcome these drawbacks several algorithms have been developed. For example, algorithm equal area dualistic sub-image histogram equalization, which divide an input histogram into sub-histogram and equalize them independently to reduce the brightness change between input and output image.

This work is divided into two parts Firstly, an improved global contrast enhancement algorithm known as layered difference representation LDR [2] is used. In this method gray-level differences, occurring frequently in the input image is been amplified in the output image in order to enhance the contrast. So the output gray level difference and transformation function are represented in a tree like layered structure. Then, at each layer, the constrained optimization problem is formulated and difference vector is obtained. Finally, difference vector at all layers are combined into an overall difference vector. Secondly contrast enhanced image are used with different filtering technique in order to conclude the best filtering technique.

IMPLEMENTATION

The overview of the method is as shown in the Figure 1 the method has three main components: global CE technique, local CE for medical image and filtering.

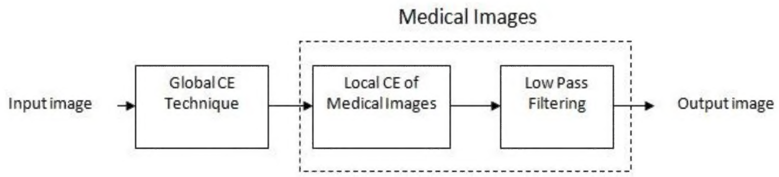


Figure 1: An Overview of Proposed Method

Global CE Technique

Global CE process uses histograms of the input image to obtain output image, the histogram processing has the advantage like straight forward implementation and computational efficiency. The disadvantage of this technique is significant data reduction.

Layered Difference Representation Method

The human visual system is more sensitive to the gray-level differences between neighboring objects then to absolute gray-levels. Thus, gray-level difference, which occurs frequently in the input image, should be amplified in the output image. Steps involved in implementation of LDR are as follows:

Step 1: Consider an 8-bit gray scale image. Let $\mathbf{x} = [x_0, x_1, \cdots, x_{255}]^T$ denotes the transformation function that maps the gray-level k in the input to the gray-level x_k in the output image.

Step 2: The input gray level difference l between k and $k + l$ is mapped to the output gray-level difference d_l^k, and the difference variable relationship can be obtained with k_l as the normalizing constant.

Step 3: Generalized equation for the output gray-level difference d_l^k is obtained by summing up estimation of the normalizing constant at each layer from y1 to y255.

Step 4: For each layer constrained optimization problem is formulated by the above steps and linear equation is obtained, i.e. $A_l y_l = d_l$, Where $A_l \in R^{(256-l)\times 255}$ a binary matrix is composed of 0 and 1, $y_l = [d_0^1, d_1^1, \cdots, d_{254}^l]^T$ is the difference vector to be determined, and $d_l = [d_0^1, d_1^1, \cdots, d_{255-l}^l]^T$ is the column vector, the elements of which are computed from the step 3.

Step 5: Difference vectors y_l are obtained by performing the intra-layer optimization at each layer, where $1 \leq l \leq 255$. Aggregation of the information in these difference vectors gives an overall difference vector $\acute{y}$. Before aggregating all the information in the $\acute{y}$, the difference vector y_l is convoluted with Gaussian kernel g_l.

Local CE Technique

HE based algorithms are widely used for contrast enhancement. The HE algorithm used here is Contrast Limited Adaptive Histogram Equalization (CLAHE) [3], one of the commonly used adaptive HE algorithms. It provides users with a control on the degree of enhancement by means of the clip limit. A higher value of the clip limit results in a higher degree of contrast enhancement, however this causes more visible noise and artifacts, particularly in homogeneous regions. The noise and artifacts resulting from this enhancement are removed in the succeeding stages using low-pass filtering process. For filtering it is important to investigate the behavior of the noise introduced by the HE so that one can design the first stage of the filtering, aiming at removing the noise with the priority of well preserving the signal variation.

Filtering Technique

Gaussian filter [1] is one of the simplest low-pass filters used for noise removal. It effectively eliminates the high-frequency noises, but blurs the fine details and sharp edges of the image. It smoothens the image by replacing the center pixel with the weighted average of the neighboring pixels.

The weights are calculated from the Gaussian function, $(x, y) = \frac{1}{2\pi\sigma^2} e^{\frac{-x^2+y^2}{2\sigma^2}}$ where σ is the standard deviation. The higher the σ value, the higher the degree of noise removal and blurring.

RESULTS

Contrast enhancement algorithm`s performance has been performed on the 7 images of the Kodak Lossless True Color Image Suite [4] and the medical images provided by RVCE health care center, Bangalore.

Assessment of contrast enhancement performance is done using four quality metrics namely absolute mean brightness error (AMBE)[5], discrete entropy (DE)[5], measure of enhancement (EME)[5], and PixDist (PD)[6]. The LDR algorithm is compared with the HE and WAHE [5] Table 1 lists the average performance of different CE on 7 test images shown in Figure 2.

Table 1: Objective Assessment of Contrast Enhancement

	INPUT	HE	WAHE	LDR
AMBE	-	6.482	7.647	**5.208**
DE	**2.154**	2.137	2.135	2.143
EME	9.878	9.485	9.265	**12.811**
PD	26.315	33.164	32.694	**34.125**

The LDR algorithm has the lowest AMBE it shows that it has lowest brightness change. As far as DE the algorithm shows poor rank. It yields the highest score in EME which infers that LDR algorithm efficiently enhance the local details along with best result in terms of PD measure also.

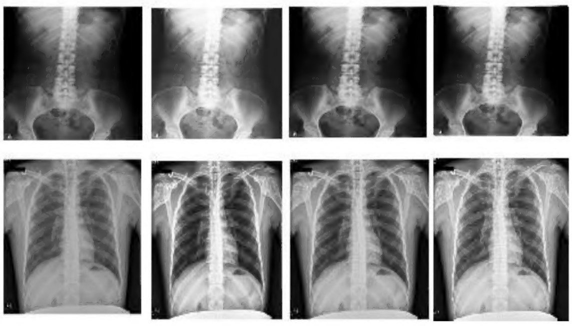
Further subjective assessment is done by comparing the images as shown in Figure 2 & Figure 3. The original image looks dull due to low contrast. HE overstretches the image, which leads to loss of image information

and looks over stretched due to high contrast variation. WAHE [5] exploits the spatial variance information to enhance the contrast on textured regions more efficiently than on homogeneous regions. Thus, it enhances object details by sacrificing background details.

Analysis shows that LDR is the best global CE technique.

(a) (b) (c) (d)

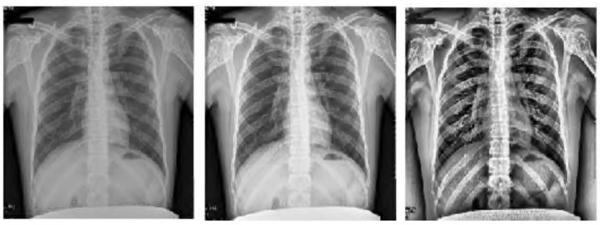
Figure 2: Contrast Enhancement Results on the Test Images "City," "Building," "Bird," (a) Original Input Images, (b) HE, (c) WAHE and (d) LDR Method



(a) (b) (c) (d)

Figure 3: Contrast Enhancement Results on the Test X-ray Images "Abdominal," "Chest," (a) Original Input Images, (b) HE, (c) WAHE and (d) LDR Method

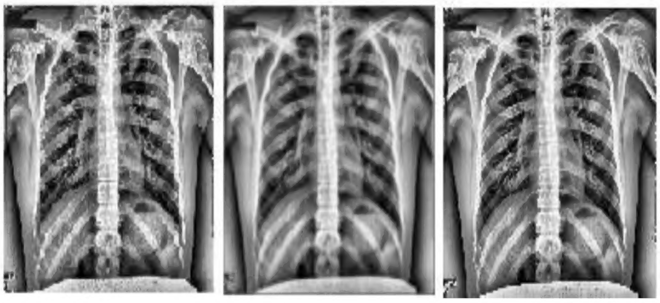
For application of filtering technique the local contrast enhancement of medical images is done to enhance the information of the images further. The output of the LDR is taken and local contrast enhancement method CLAHE [3] is applied with fixed Clip Limit of 0.08 and Num Tiles [8, 8]. The Figure 4 illustrates the results obtained.



(a) (b) (c)

Figure 4: Contrast Enhancement Results on the Test X-ray Images (a) Original Input Images, (b) LDR Method, (c) CLAHE

As CLAHE is the LCE method it produces more noise or distortion in the image which leads to the loss of the image information, so different filtering methods are applied. The Figure 5 illustrates the results obtained.



(a) (b) (c)

Figure 5: Filtering Technique Results on the Test X-ray Images (a) Gaussian Filtering, (b) Anisotropic Diffusion, (c) Bi-Lateral Filtering

In the Figure 5 the visual verification justifies that Gaussian filtered image enhance the local and structural details

For the assessment of image quality of the filtered images we use quality metrics PSNR [9] (peak signal to noise ratio) and MSE [9] (mean square error). Table 2 illustrates the results

Table 2: Objective Assessment of Filtered Images

Filtering Types	MSE	PSNR
Anisotropic diffusion	79.48	29.1621524
Bilateral filter	79.01	29.1877707
Gaussian filter	78.81	29.1988983

The Table 2 shows the comparative study of the different filters over radiographic images and Gaussian filter scores the best result with lowest MSE and highest PSNR which are darken in the Table 2

CONCLUSIONS

Different filtering techniques produced different images. The best image in terms of clarity and removing artifacts is the image obtained from Gaussian filtering technique.

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